Validation of Surface-Only Flux Algorithms

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Background (Part 1)

CERES uses several Surface-Only Flux Algorithms (SOFA) to compute SW and LW surface fluxes in addition to the more precise model used by SARB. The SOFA algorithms include:

LPSA/LPLA:
Langley Parameterized SW/LW Algorithm

		Model A	Model B	Model C
SW	Clear	Li et al.	LPSA	--
	All-Sky	--	LPSA	--
LW	Clear	Inamdar and Ramanathan	LPLA	Zhou-Cess
	All-Sky	--	LPLA	Zhou-Cess

SOFA References:

SW A: Li et al. (1993): *J. Climate*, **6**, 1764-1772.
SW B: Darnell et al. (1992): *J. Geophysical Research*, **97**, 15741-15760.
SW B: Gupta et al. (2001): *NASA/TP-2001-211272*, 31 pp.
LW A: Inamdar and Ramanathan (1997): *Tellus,* **49B**, 216-230.
LW B: Gupta et al. (1992): *J. Appl. Meteor.,* **31**, 1361-1367.
LW C: Zhou et al. (2007): *J. Geophysical Research*, **112**, D15102.
SOFA: Kratz et al. (2010): *J. Appl. Meteor. Climatology*, **49**, 164-180.
SOFA: Gupta et al. (2010): *J. Appl. Meteor. Climatology,* **49**, 1579-1589.
FLASH: Kratz et al. (2014): *J. Appl. Meteor. Climatology*, **53**, 1059-1079.

Background (Part 2)

- The SOFA LW and SW Models are based on rapid, highly parameterized TOA-to-surface transfer algorithms to derive the surface fluxes.
- LW Model A (clear-sky only), LW Model B (all-sky) and SW Model A (clear-sky only) were incorporated at the start of the CERES project.
- SW Model B (all-sky) was adapted for use in the CERES processing shortly before the launch of the CERES instrument on the TRMM satellite.
- The Edition 2B LW and SW surface flux results underwent extensive validation [Kratz et al., 2010].
- The ongoing validation process led to improvements to the LW models [Gupta et al., 2010].
- LW Model C (all-sky) [Zhou et al., 2007] was introduced into the Edition 4 processing to maintain two independent LW algorithms after the broadband LW Channel was chosen to replace the CERES Window Channel for CERES FM-6 and the next generation Radiation Budget Instrument (RBI).
- LW and SW Models B were incorporated into the FLASHFlux effort to produce a rapidly available Environmental Data Record [Kratz et al., 2014]

Recent and Future Improvements to the Surface-Only Flux Algorithms

SW Model Improvements: 1) Replacing the ERBE albedo maps with Terra maps greatly improved the SW retrievals, most notably for polar regions. 2) Replacing the original WCP-55 aerosols properties with monthly MATCH/OPAC datasets while also replacing the original Rayleigh molecular scattering formulation with the Bodhaine et al., (1999) model significantly improved SW surface fluxes for clear conditions. 3) To account for the short term aerosol variability we have incorporated daily MATCH aerosol data into Edition 4. 4) Using a revised empirical coefficient in the cloud transmission formula has improved the SW surface fluxes for partly cloudy conditions. 5) Work continues on the improvement of the cloud transmission method for Edition 4 clouds. Use of SSF-82 (cloud layer note) may reduce uncertainties in surface flux retrievals.

LW Model Improvements: 1) Constraining the lapse rate to 10K/100hPa (roughly the dry adiabatic lapse rate) improved the derivation of surface fluxes for conditions involving surface temperatures that greatly exceeded the overlying air temperatures, see Gupta et al. (2010). 2) Limiting the inversion strength to -10K/100hPa for the downward flux retrievals provided the best results for cases involving surface temperatures that were much below the overlying air temperatures (strong inversions).

SW and LW Model Improvements: 1) The availability of ocean buoy measurements may improve surface flux retrievals by providing validation over oceans.

Parameterized models for fast computation of surface fluxes for both CERES and FLASHFlux

Dataset	CERES 2B	CERES 4
Clear-Sky TOA albedo Terra	48 month ERBE	70 month Terra
Clear-Sky TOA albedo Aqua	46 month Terra	70 month Terra
Clear-Sky Surf. albedo	46 month Terra	70 month Terra
TOA to Surface albedo transfer	Instantaneous	Monthly average
Spec. Corr. Coef.	CERES 2B	CERES 4A
Cos (sza) dependence of Surface Flux	LPSA	Briegleb-type
Cloud Algorithm Terra	Terra Ed2	Terra/Aqua Ed4
Cloud Algorithm Aqua	Aqua Ed2	Terra/Aqua Ed4
SW aerosol dataset	WCP-55	MATCH/OPAC
Rayleigh Treatment	Original LPSA	Bodhaine et al (1999), JAOT.
Ozone Range Check	0 to 500 DU	0 to 800 DU
Twilight cutoff		New
Cloud transmission empirical coefficient	0.80	0.75
LW high temperature surface correction	No	Maximum Lapse Rate 10K/100hPa
LW Inversion correction	No	Maximum Inversion Strength -10K/100hPa

Status of Total Solar Irradiance (TSI) Measurements

The SORCE TIM (Total Irradiance Monitor) began producing TSI data on February 25, 2003. A battery failure on SORCE, however, stopped regular production during the period from July 16, 2013 through March 4, 2014.

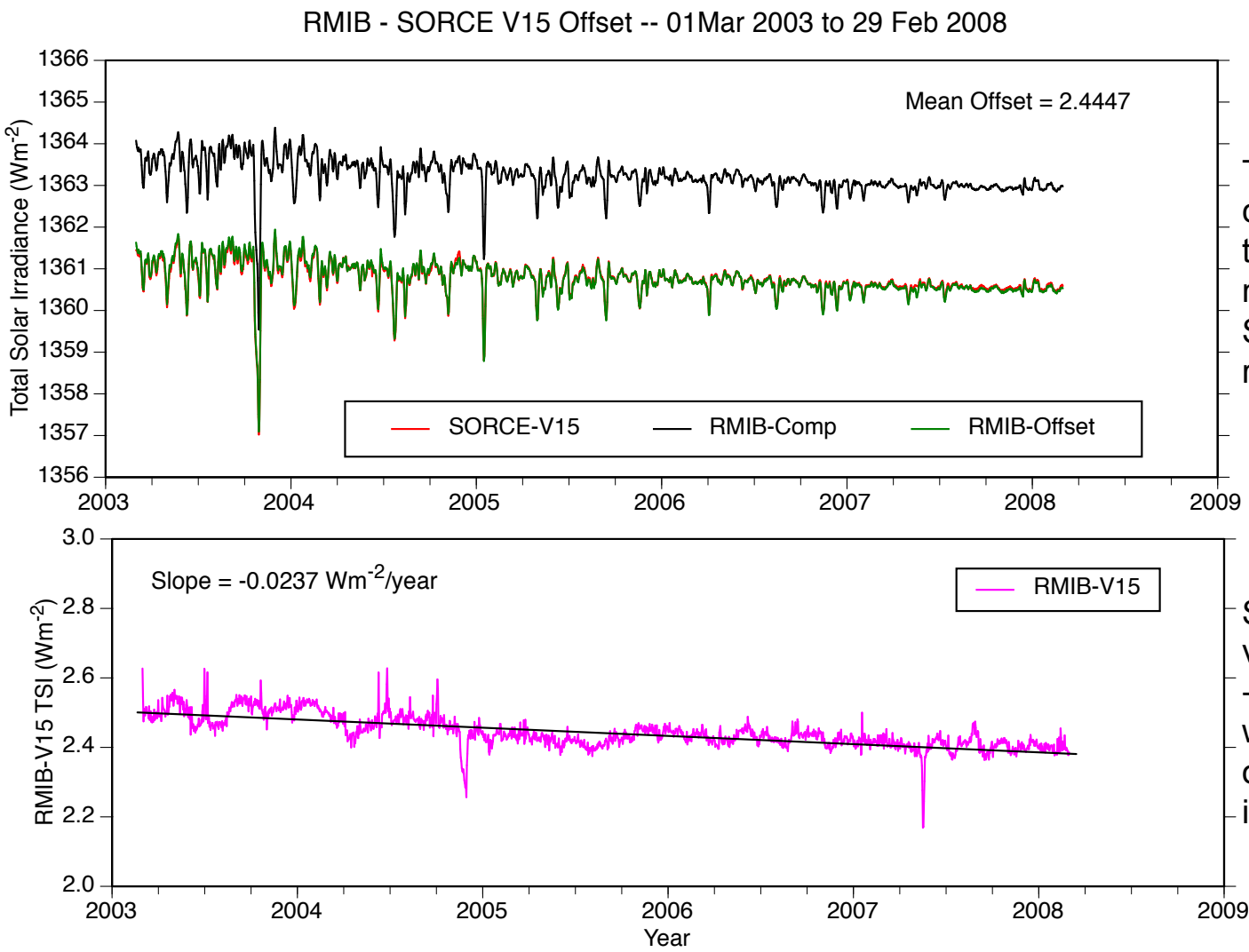
Thus, for the period from July 1, 2013 though October 31, 2013 we used the RMIB composite TSI data provided by S. Dewitte.

The RMIB data, however, requires an offset from the DIARAD VIRGO solar minimum value of ~1363 W/m^2 to match the SORCE solar minimum of ~1361 W/m^2. Note, for CERES Edition 4 processing all TSI data are offset to match SORCE TSI Version 15. The offset is: V15 – V17 = –0.0049 W/m^2.

In the meantime, the TSI Calibration Transfer Experiment (TCTE) was launched into orbit on November 19, 2013 and began producing TSI data on an irregular basis on December 16, 2013, and more recently, on a regular daily basis since January 1, 2015.

The SORCE instrument resumed data production on a daily basis on March 5, 2014. CERES subsequently resumed merging the SORCE TSI data into the CERES processing beginning on November 1, 2014.

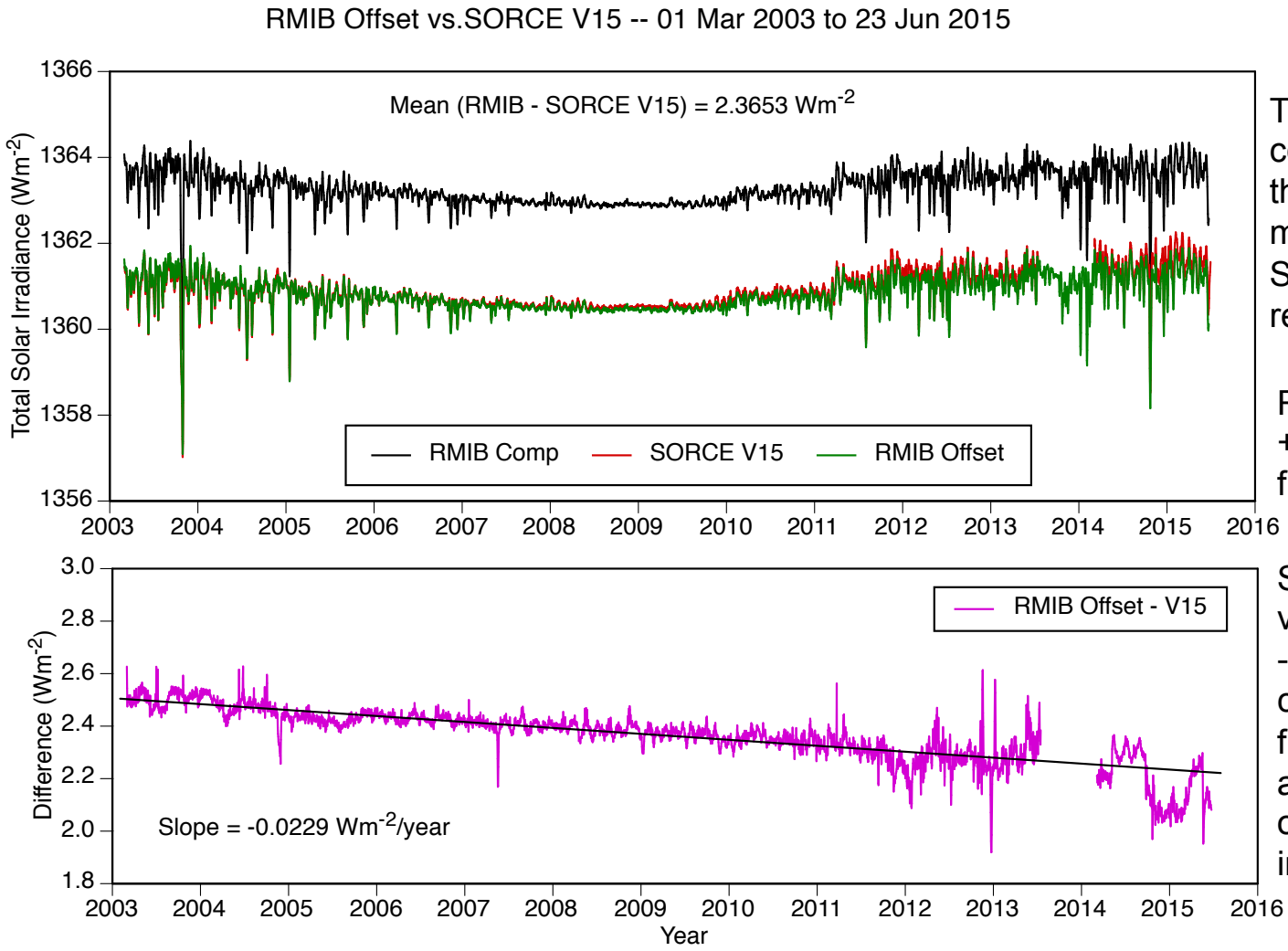
Comparison of TSI data [SORCE(V15) versus RMIB] for the 5-year overlap period 1-Mar-2003 to 29-Feb-2008



This timeframe corresponds to the first 60 months of the SORCE data record

Slope of RMIB vs. SORCE is -0.0237 W/m^2/y which yields an offset of 1 W/m^2 in 42.19 years

Comparison of SORCE(V15) and RMIB for the timeframe: 1-Mar-2003 to 23-Jun-2015

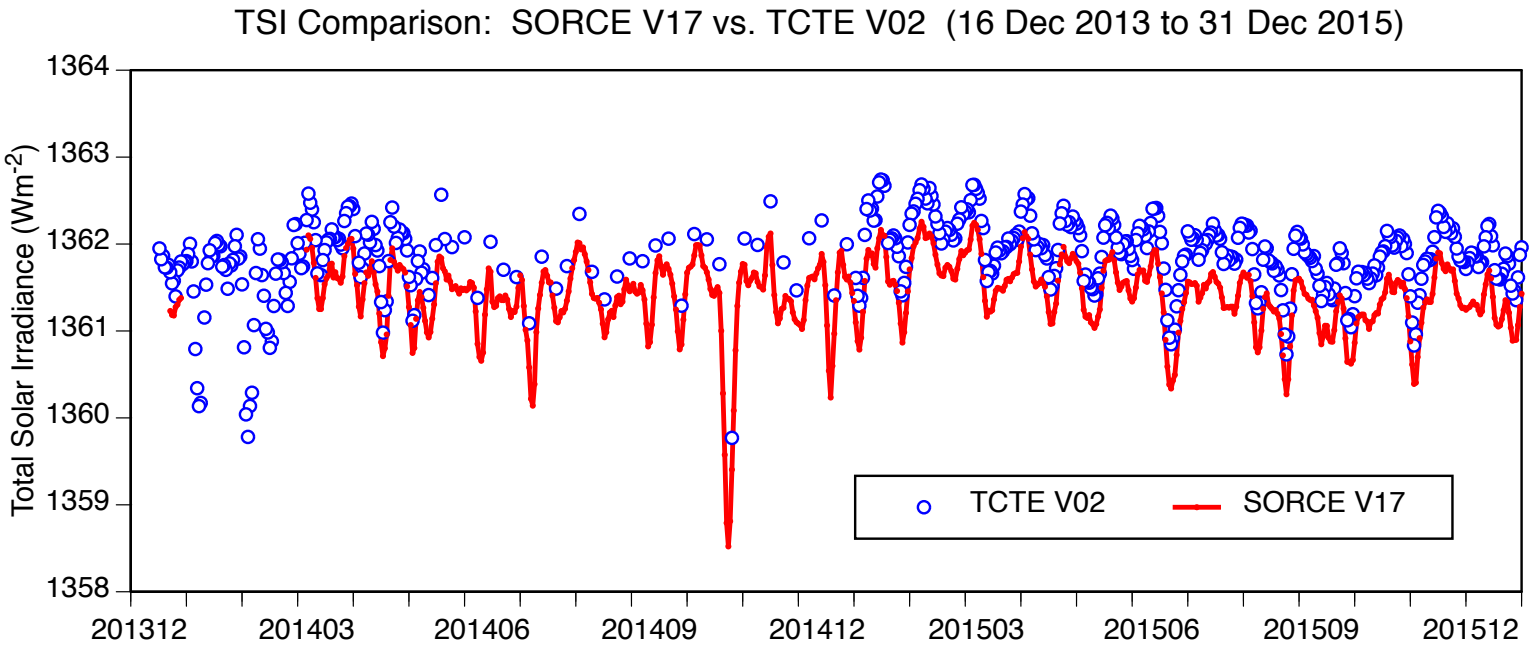


This timeframe corresponds to the first 148 months of the SORCE data record

RMIB offset by +2.3653 W/m^2 from SORCE

Slope of RMIB versus SORCE -0.0229 W/m^2/y corresponds to first 120 months and yields an offset of 1 W/m^2 in 43.67 years

Comparison of SORCE(V17) and TCTE(V02) Daily/Weekly Total Solar Irradiance Retrievals



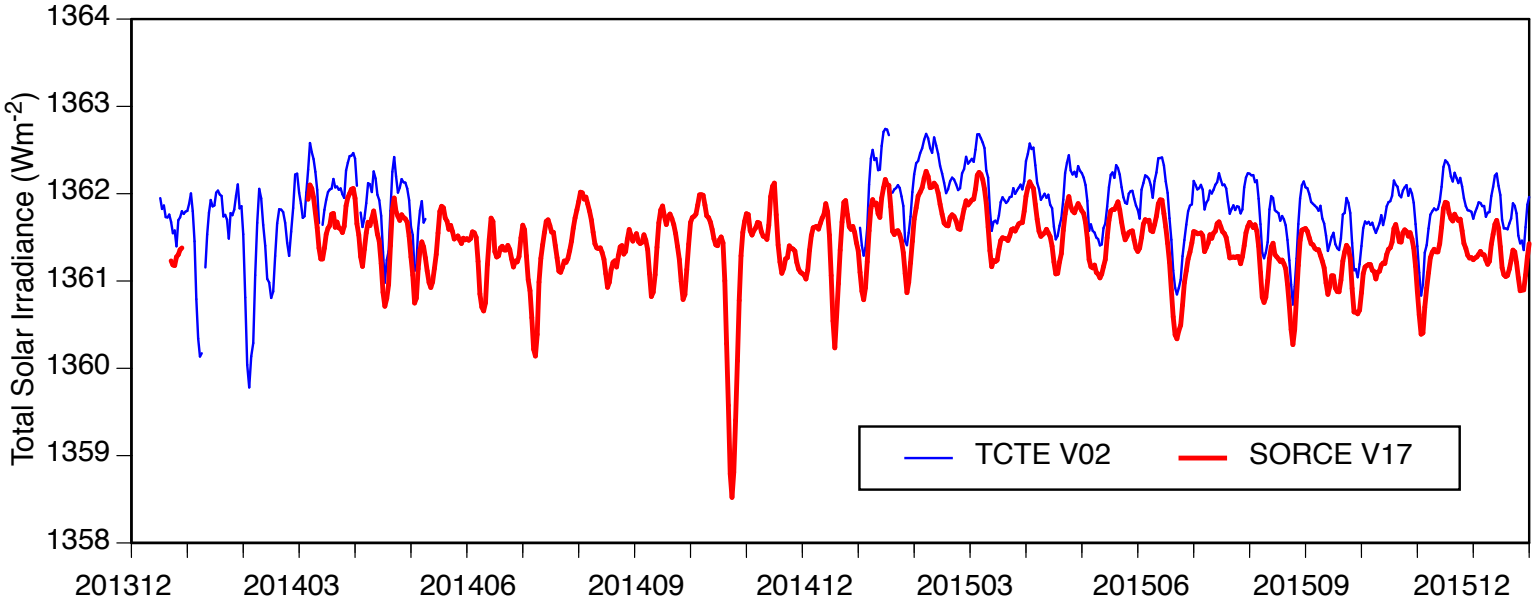
SORCE: 1 value/day, Dec 22, 2013 through Dec 28, 2013, and 1 value/day Mar 5, 2014 through Mar 31, 2016; Absolute Accuracy: ±0.48 W/m^2 at 1361 W/m^2

TCTE: 1 value/day, Dec 16, 2013 through May 8, 2014, 1 value/week May 11, 2014 through Dec 31, 2014, 1 value/day Jan 1, 2015 through Mar 31, 2016; Absolute Accuracy: ±1.36 W/m^2 at 1361 W/m^2

SORCE minus TCTE (Jan 1, 2015 to Dec 31, 2015) is -0.4879 ± 0.0599 W/m^2
SORCE minus TCTE (Jan 1, 2015 to Mar 31, 2016) is -0.4965 ± 0.0582 W/m^2

Comparison of SORCE(V17) and TCTE(V02) Daily Total Solar Irradiance Retrievals

TSI Comparison: SORCE V17 vs. TCTE V02 (16 Dec 2013 to 31 Dec 2015)



SORCE: 1 value/day, Dec 22, 2013 through Dec 28, 2013, and 1 value/day Mar 5, 2014 through Mar 31, 2016; Absolute Accuracy: ±0.48 W/m^2 at 1361 W/m^2

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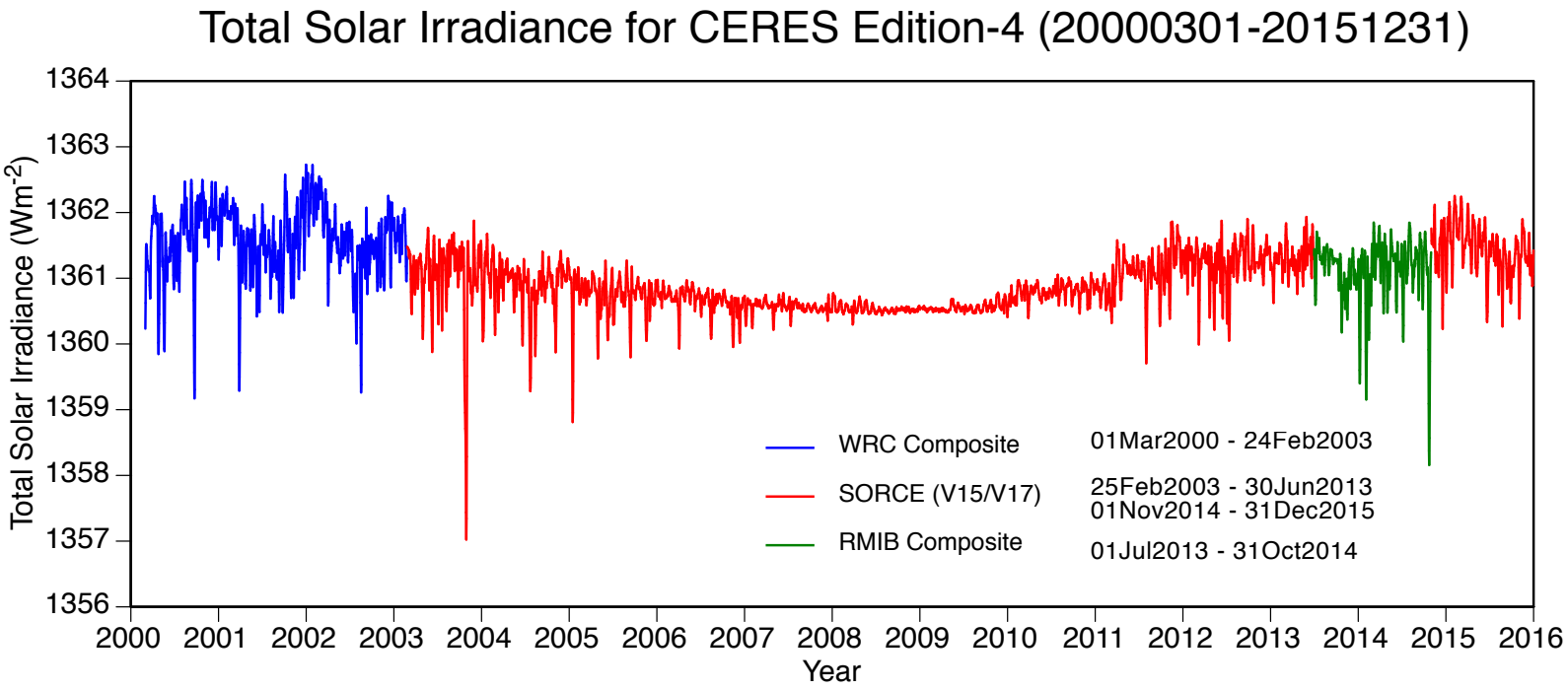
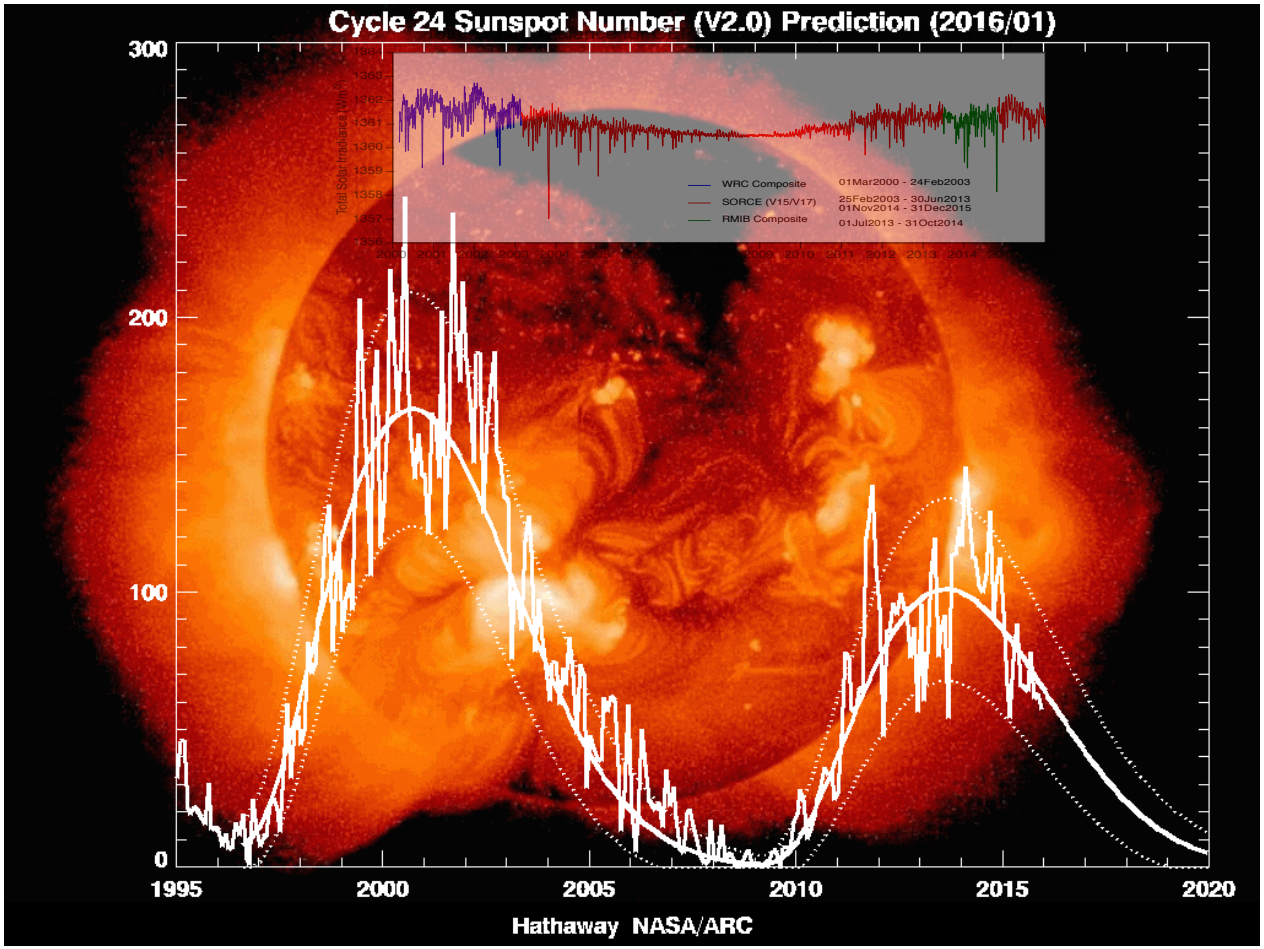
TSI composite data from WRC, SORCE(V15) and RMIB for the Timeframe of CERES Terra, Aqua & NPP

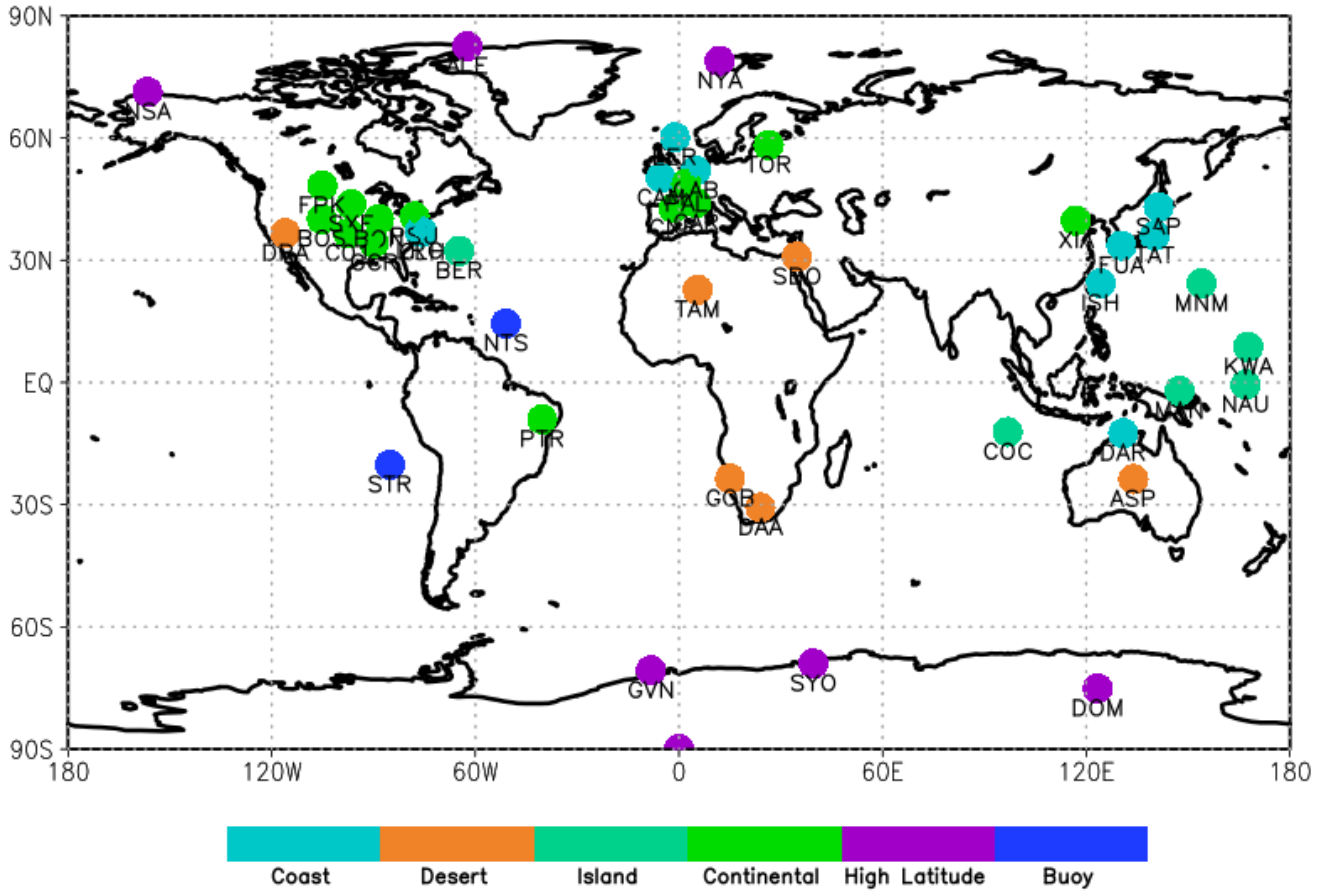


For CERES Ed4, all TSI data are offset to match SORCE TSI Version 15

Sunspot Numbers for Solar Cycles 23 & 24



Surface Sites Available for Validation of Terra & Aqua Ed4, and NPP Ed1



Coastal

Desert

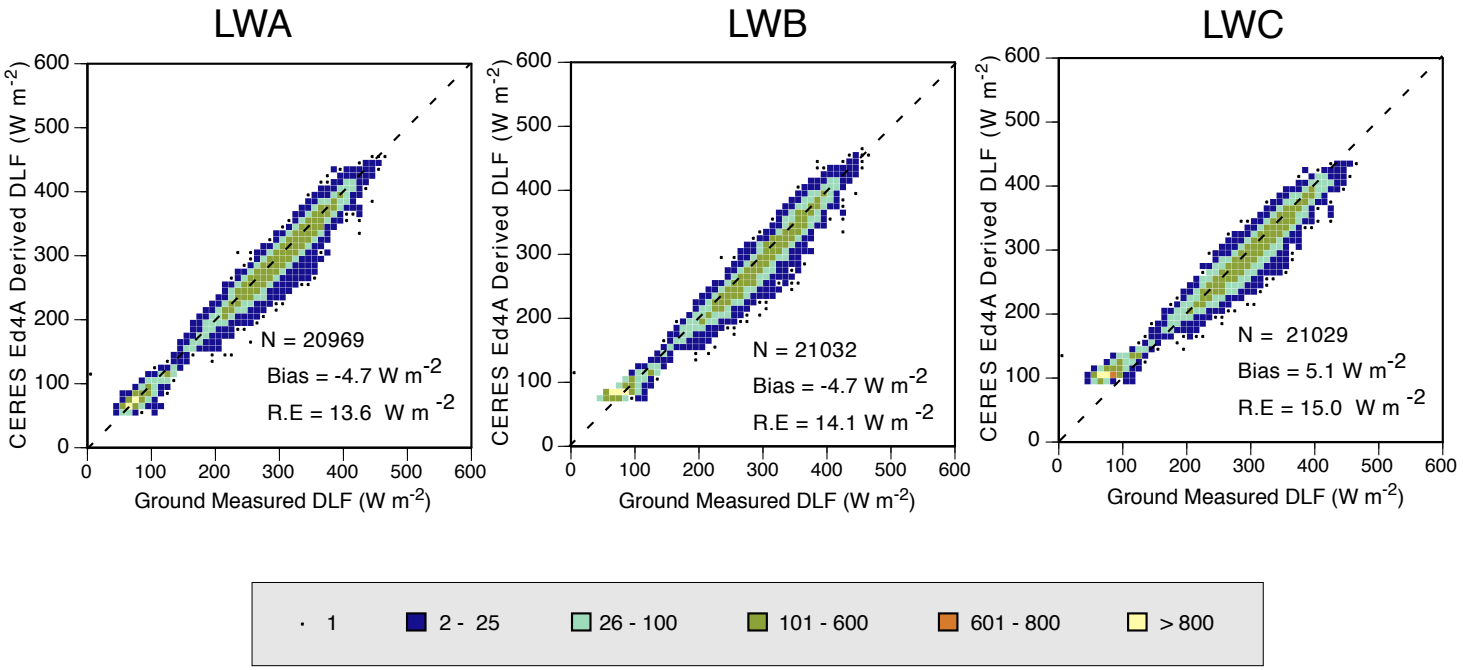
Island

Continental

Polar

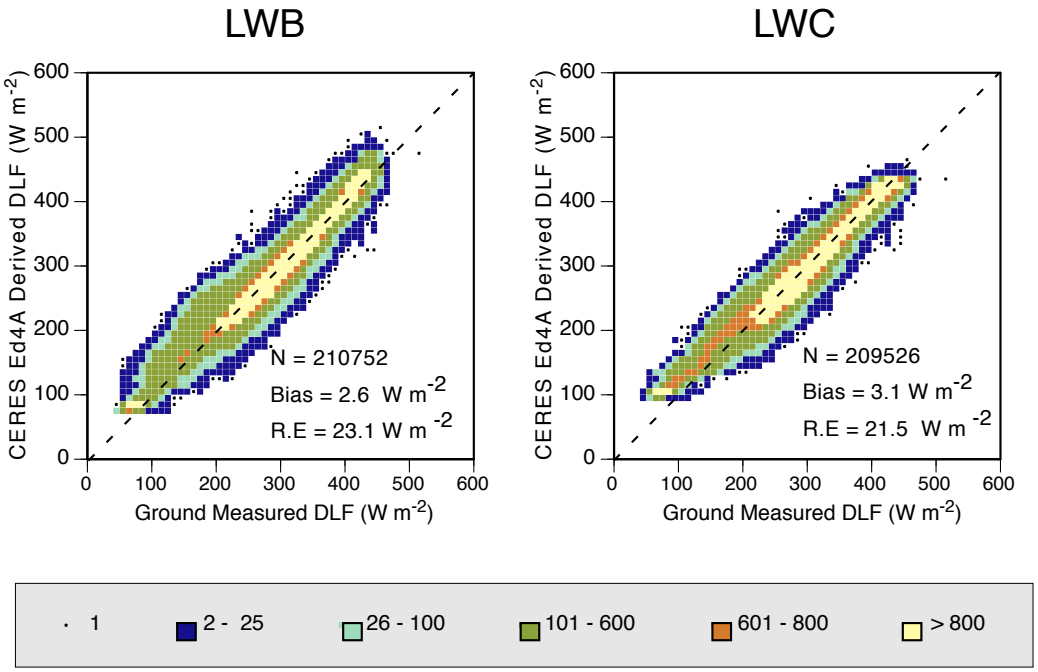
Ocean

CERES Terra Edition 4 LW Ground Validation (Global) Clear-Sky



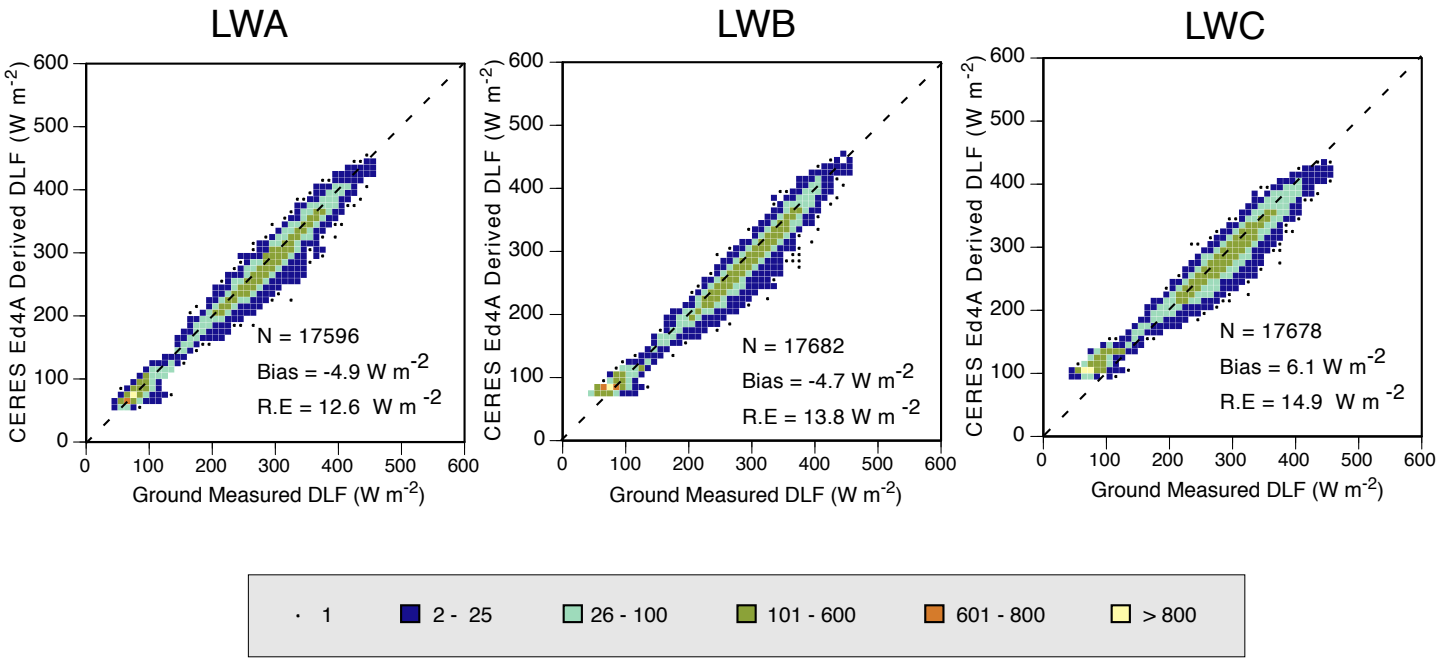
Combined LW Ground Validation for Terra (4/2000 through 12/2014).

CERES Terra Edition 4 LW Ground Validation (Global) All-Sky



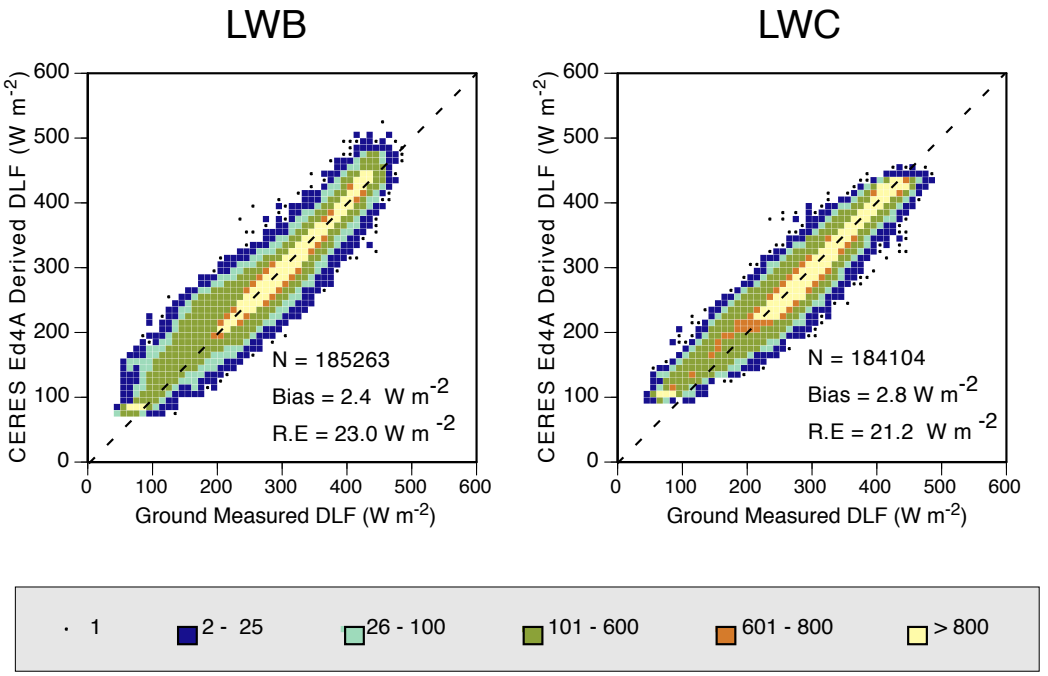
Combined LW Ground Validation for Terra (4/2000 through 12/2014).

CERES Aqua Edition 4 LW Ground Validation (Global) Clear-Sky



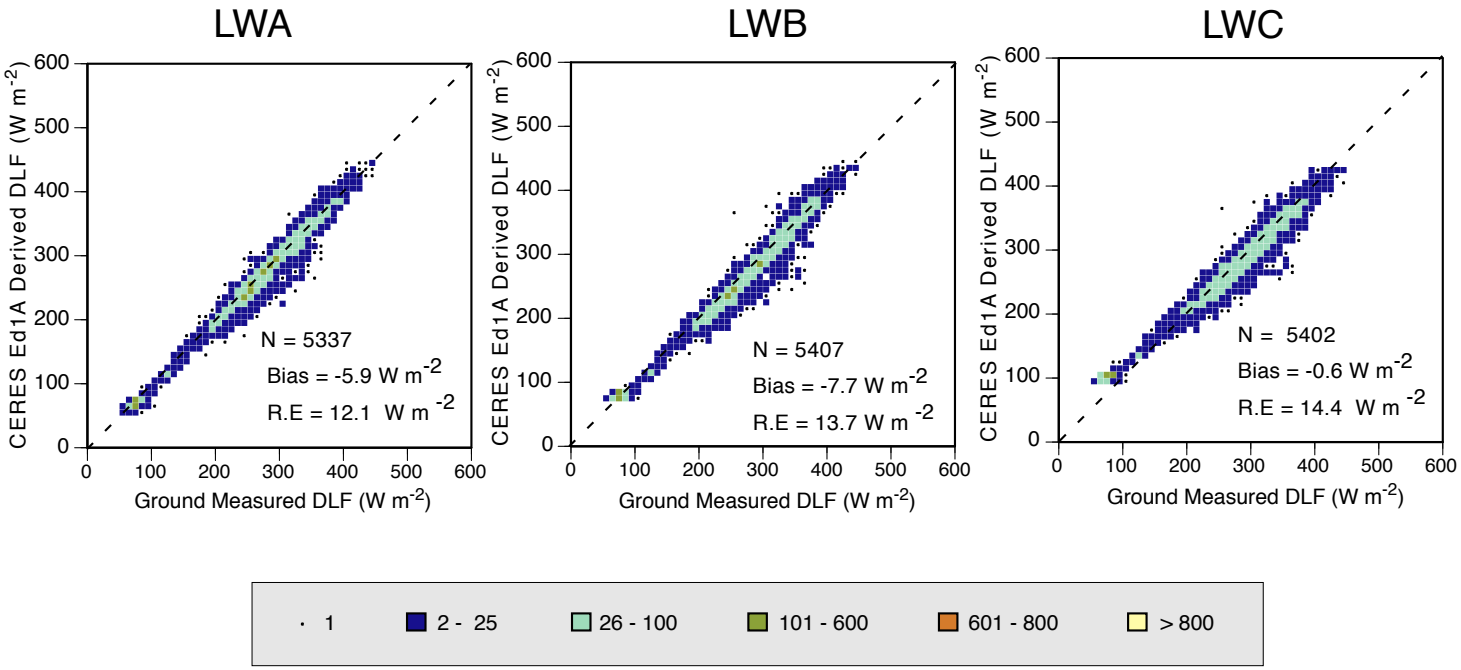
Combined LW Ground Validation for Aqua (7/2002 through 12/2014).

CERES Aqua Edition 4 LW Ground Validation (Global) All-Sky



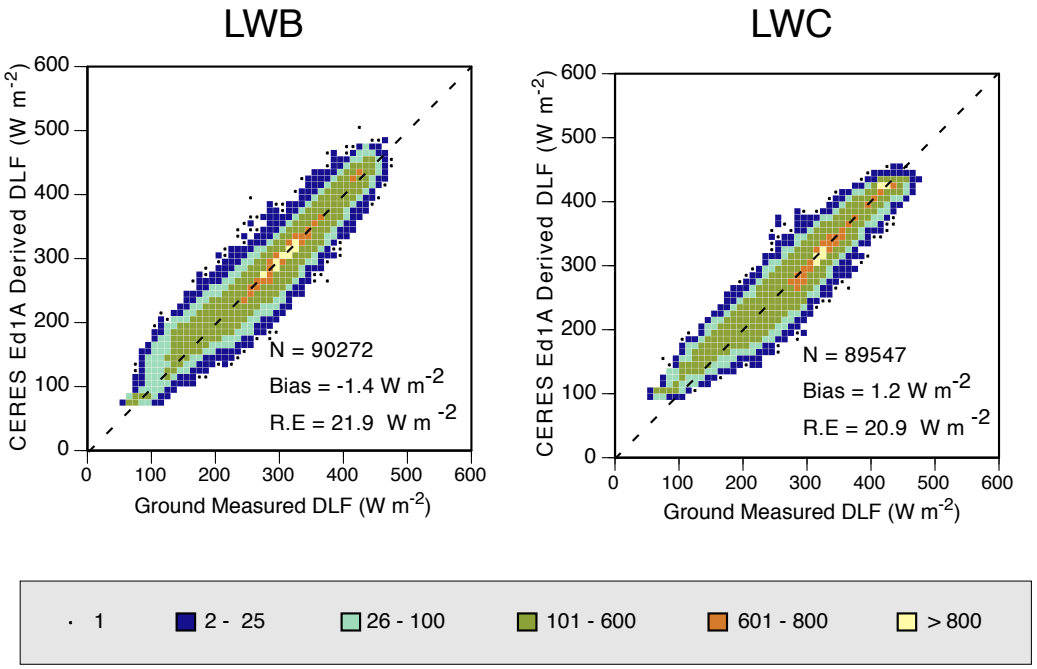
Combined LW Ground Validation for Aqua (7/2002 through 12/2014).

CERES NPP Edition 1 LW Ground Validation (Global) Clear-Sky



Combined LW Ground Validation for NPP (1/2012 through 12/2015).

CERES NPP Edition 1 LW Ground Validation (Global) All-Sky



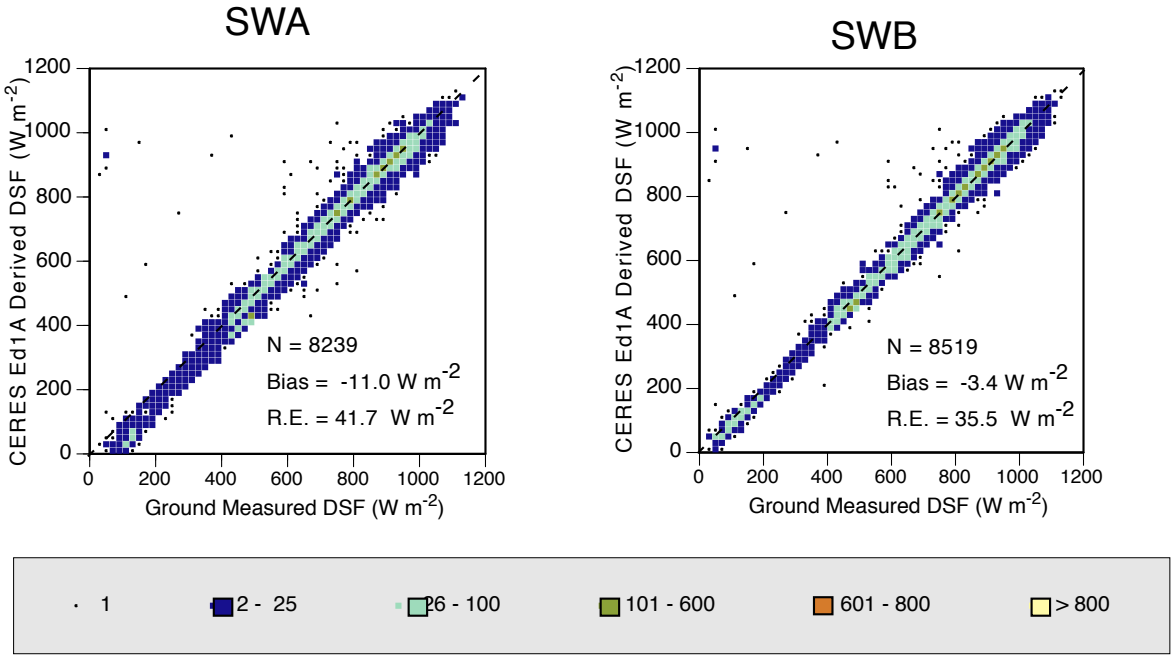
Combined LW Ground Validation for NPP (1/2012 through 12/2015).

LW Surface Flux Results

The Terra, Aqua and NPP LW fluxes derived for Clear Sky conditions show low biases ≈±6 W/m^2, and relatively low uncertainties ≈12 to 15 W/m^2.

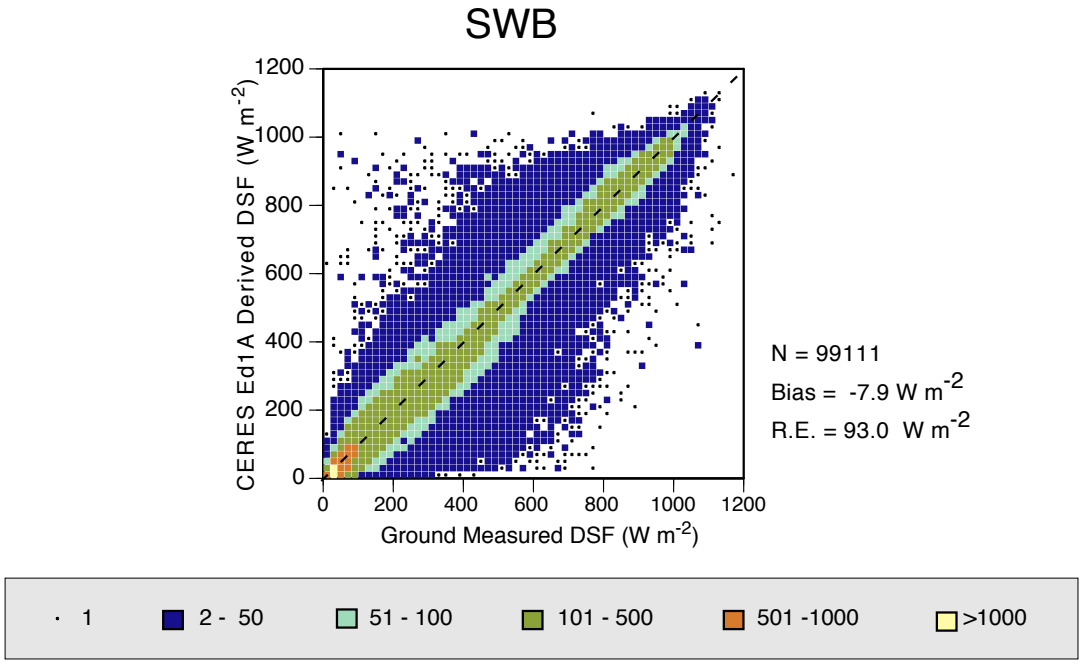
The Terra, Aqua and NPP LW fluxes derived for Cloudy Sky conditions show low biases ≈±3 W/m^2, and moderate uncertainties ≈20 to 23 W/m^2.

CERES Terra Edition 4 SW Ground Validation Global Clear-Sky



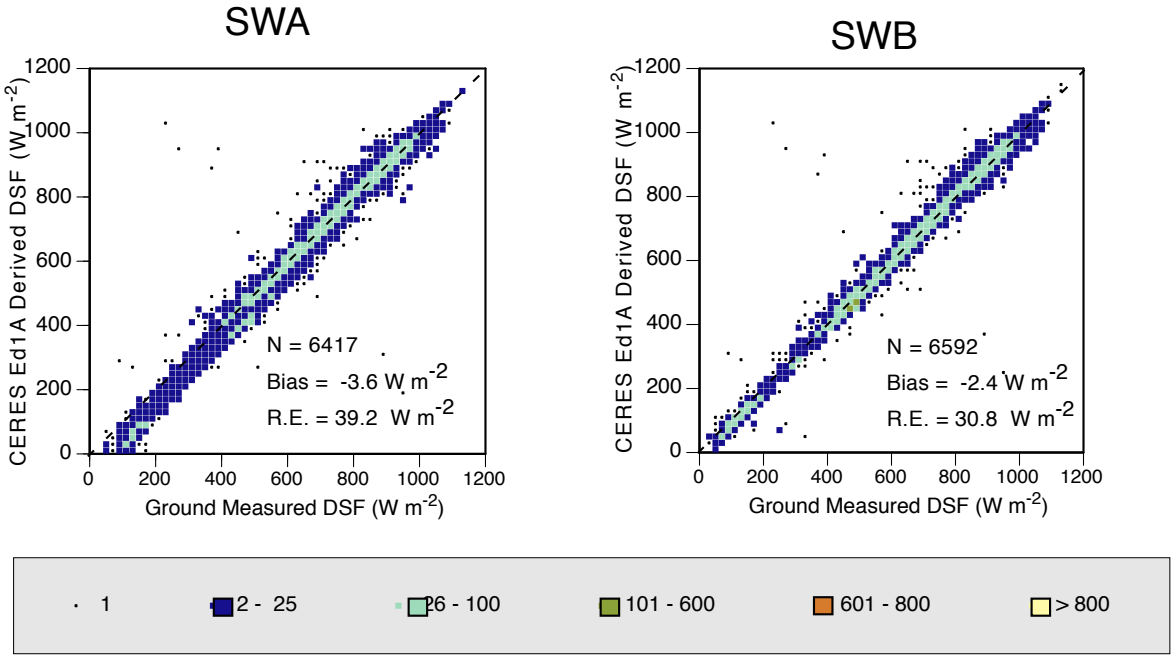
Combined SW Ground Validation for Terra (4/2000 through 12/2014).

CERES Terra Edition 4 SW Ground Validation (Global) All-Sky



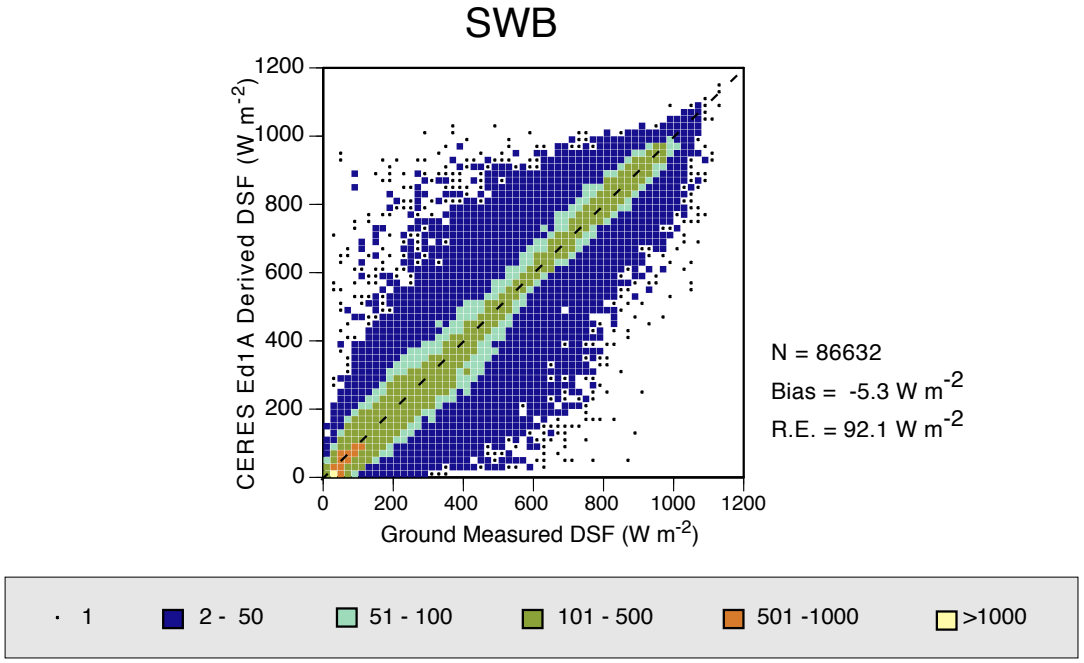
SWB Ground Validation for Terra (4/2000 through 12/2014).

CERES Aqua Edition 4 SW Ground Validation Global Clear-Sky



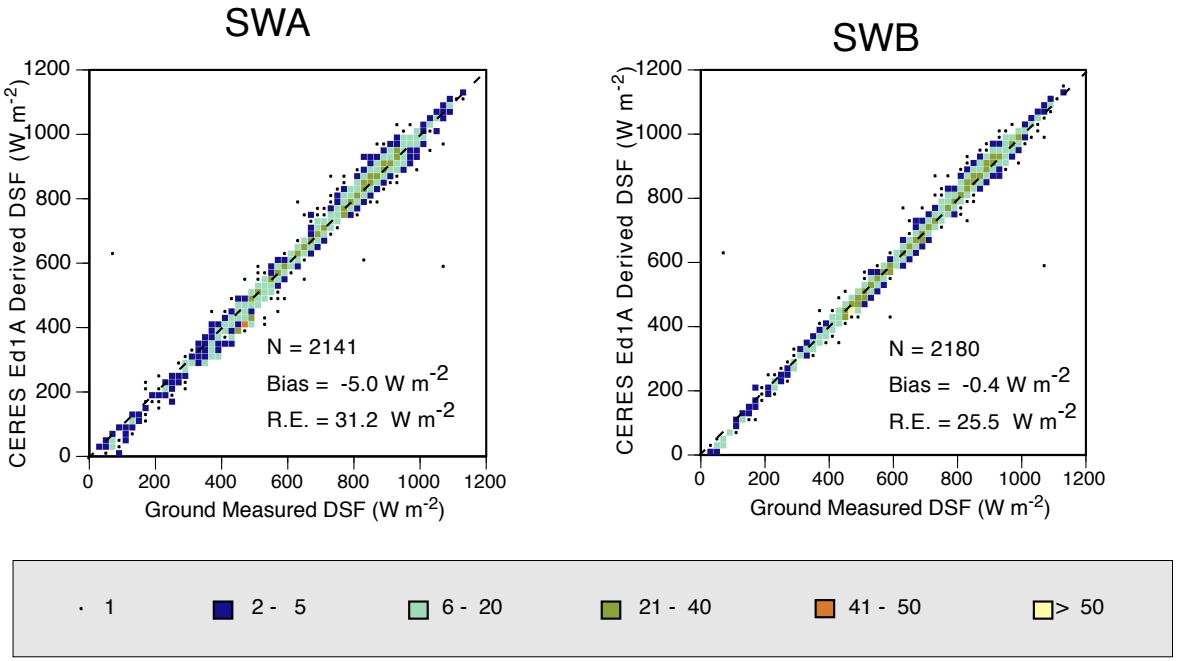
Combined SW Ground Validation for Aqua (7/2002 through 12/2014).

CERES Aqua Edition 4 SW Ground Validation (Global) All-Sky



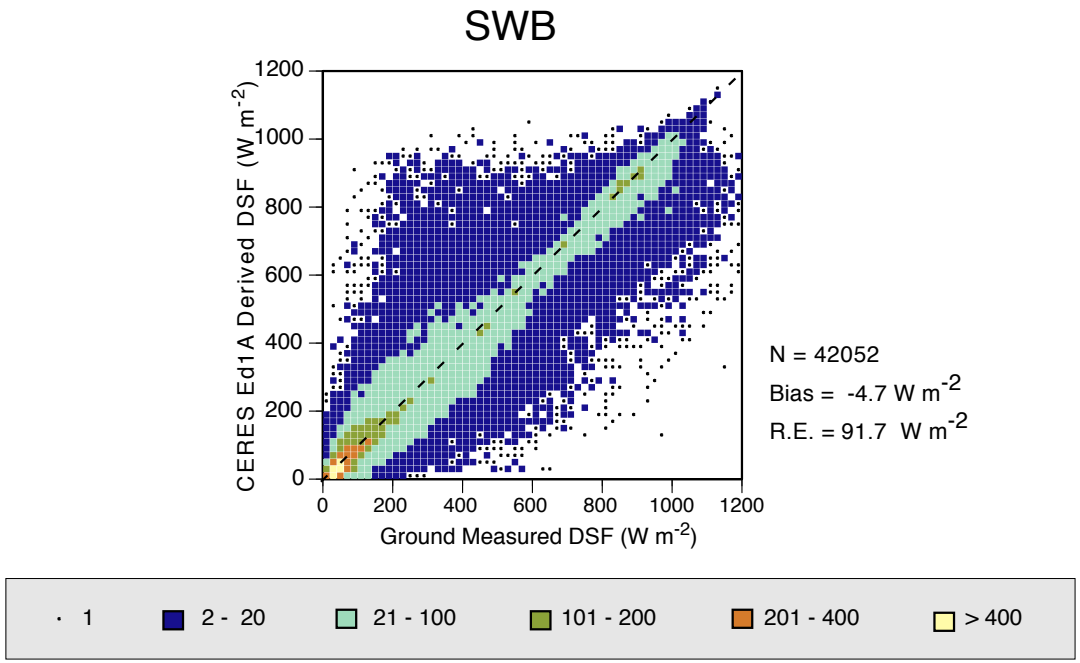
SWB Ground Validation for Aqua (7/2002 through 1/2014).

CERES NPP Edition 1 SW Ground Validation (Global) Clear-Sky



Combined SW Ground Validation for NPP (1/2012 through 12/2015).

CERES NPP Edition 1 SW Ground Validation (Global) All-Sky



SWB Ground Validation for NPP (1/2012 through 1/2015).

SW Surface Flux Results

The Terra, Aqua and NPP SW fluxes derived for Clear Sky conditions show relatively low biases ≈0 to -10 W/m^2, and moderate uncertainties ≈25 to 35 W/m^2.

The Terra, Aqua and NPP SW fluxes derived for Cloudy Sky conditions show relatively low biases ≈-5 to -10 W/m^2, but large uncertainties ≈90 W/m^2.

Our current effort is focused on finding methods to reduce the large uncertainties in the retrieved SW Cloudy Sky surface fluxes.

Conclusions for SOFA Ed4 algorithms

Validation studies have demonstrated that revisions to both the LW algorithms and the SW algorithms (for clear to partly cloudy conditions) appear to be working well, though further revisions to the cloud transmission method and/or overcast albedo method are needed for SW Model B. Current attention is focused on the cloud transmission data, and whether use of SSF-82 (cloud layer note) could be used to refine the results.

An analysis of the LW and SW surface only flux algorithm results using the Edition 4 inputs, especially those from the Clouds Subsystem, has indicated improved accuracies for most locations.

The Terra, Aqua and NPP flux retrievals show the anticipated results.